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Art and Science: A Philosophical Sketch of Their Historical Complexity and Codependence

ABSTRACT

To analyze the relations between art and science, philosophers and historians have developed different lines of inquiry. A first type of inquiry considers how artistic and scientific practices have interacted over human history. Another project aims to determine the contributions (if any) that scientific research can make to our understanding of art, including the contributions that cognitive science can make to philosophical questions about the nature of art. We rely on contributions made to these projects in order to demonstrate that art and science are codependent phenomena. Specifically, we explore the codependence of art and science in the context of a historical analysis of their interactions and in the context of contemporary debates on the cognitive science of art.

Philosophers and historians have developed different types of research projects to analyze the relations between art and science. A first type of inquiry considers how artistic and scientific practices have interacted over human history. Another line of research aims to determine the contributions (if any) that scientific methods can make to our understanding of art, including the contributions that cognitive science can make to philosophical questions about the nature of art. In this article, we critique the "Two Cultures" view that separates art history from the history of science and holds that scientific methods are irrelevant to our philosophical understanding of art. By contrast to this view, we argue that the arts and the sciences are codependent phenomena. Specifically, we explore the codependence of the arts and the sciences in the broad context of a historical analysis of their interactions and in the specific context of contemporary debates on the cognitive science of art.

I. THE CODEPENDENCE THESIS

According to a conception that belatedly emerged in the history of art theory, art essentially differs from science because the cognitive and social manifestations of the arts fundamentally differ from those that characterize the sciences. A common way to defend this simple image consists in deriving it from the *Two Cultures* view (Snow 1993; see Blair and Grafton 1992 for a historical analysis). This view assumes that the culture of the arts and humanities fundamentally differs from the culture of the sciences. A typical defender of the Two Cultures perspective may emphasize the importance of personal experience and idiographic knowledge in artistic culture and contrasts these with the quest for impersonal objectivity and nomothetic explanations of natural phenomena in science (see, for example, Popper 1979, who characterizes science as a quest for objectivity). The conceptions of art holding that it is in principle impossible for science to explain the nature and values of the arts are similarly conducive to the Two Cultures view. To those who assume the Two Cultures view, the arts and the sciences are two independent realms of human endeavor.

Although they might not explicitly defend the Two Cultures view, several philosophers have maintained the status quo associated with that view by defending theses consistent with it. For example, several philosophers have held that works of art are devised to elicit subjective and idiographic processes, such as an act of intuiting expressive communication (Croce 1909), having a unified experience of aesthetic pleasure (Beardsley 1969), or valuing an object from an aesthetic perspective (Anderson 2000). Recently, a number of analytic philosophers have radically called into question the explanatory value of the contemporary biological and cognitive sciences of art. For example, among the sternly *pessimistic* assessments of the science of art, Graham McFee (2011) maintains that contemporary neuroscience is *irrelevant* to our philosophical reflections upon an art form like dance. Other philosophers opt for less radical forms of pessimism. As a self-declared *moderate pessimist* engaged with neuroscience, David Davies (2013) argues that recent psychological empirical research on dance does not directly settle any of the core normative and ontological questions investigated by the philosophy of dance (for example, specifying the factors that make dance an art form). Davies's concerns echo other comparable assessments made by moderate pessimists (Hyman 2010; Noë 2015; Langer 2016) and by a few moderate optimists (Seeley 2011, 2013; Bullot and Reber 2013), who argue that neuroaesthetics and the cognitive neuroscience of art rest on a mistaken ontology of art and an unreasonably reductionist methodology.

The pessimistic views recently expressed by analytic philosophers of art may surreptitiously prolong the contentious influence of the Two Cultures view. To propose an alternative conceptual framework to this divisive pessimism, we devote this article to a thesis that undermines the Two Cultures view: we defend a *codependence thesis* holding that a history of dependence relations has linked the arts and the sciences and continues to link them in the current historical context. We use *dependence relations* to denote networks of cognitive, social, and technological interactions between artistic and scientific phenomena. One of the faults of the Two Cultures view is to omit the existence and significance of these interactions, and therefore to silence the history of relations between artistic and scientific cultures.

II. THE DEPENDENCE OF SCIENTIFIC COGNITION ON ARTISTIC INNOVATION AND AESTHETIC SKILLS

Catherine Elgin introduced a seminal view that lends support to the codependence thesis. Her claim is that "the arts and the sciences perform many of the same cognitive functions, both serving to advance understanding" (1993, 13). To establish that the arts and the sciences tap into a shared pool of cognitive resources, Elgin relies on the notion of *exemplification* understood in Goodman's (1968) sense: an exemplification is an item that at once refers to and instantiates a category. Goodman's example is a carpet sample. Other examples of exemplification include diagrams and notational systems such as musical scores.

Exemplification occurs in both the arts and the sciences, where it serves functions in relation to highlighting, underscoring, conveying, or summarizing information. Moreover, exemplification of unsuspected features may elicit conceptual change. As noted by Elgin, "When *The Rite of Spring* exemplifies tonal patterns classical music cannot accommodate, or the Michelson–Morley experiment exemplifies phenomena classical physics cannot coherently describe, the inadequacies of available conceptions are made manifest" (1993, 17).

The use of exemplification in both the arts and the sciences therefore suggests that the arts and the sciences rely on at least one common toolbox of cognitive skills (that is, those perceptual and inferential skills required for comprehending and using exemplification). If the arts and the sciences sometimes rely on the same core cognitive toolbox, then this shared cognitive foundation may lead them to be mutually dependent in a number of contexts. Recent research in cognitive science—including Thagard (2005), Carruthers, Stich, and Siegal (2002), Seeley (2011), Bullot and Reber (2013)—and the historical philosophy of the relations between art and science—including McAllister (1989), Freedberg (2003), Hecht, Schwartz, and Atherton (2003), and S. Davies (2012)—provides a diverse body of evidence to support Elgin's claim and our codependence thesis. This can be shown by reviewing a number of key dependence relations linking artistic and scientific practices.

A first, remarkable relation of dependence occurs when aesthetic and artistic skills make an essential contribution to epistemic processes and scientific discoveries. We may abbreviate this relation as follows: *artistic innovation → scientific innovation*. Western science since the Renaissance offers multiple instances of the indispensable contributions of artistic skills to scientific learning and innovation. There is abundant evidence of this dependence relation in the epistemic roles played by illustrations and pictorial exemplifications in a variety of scientific contexts (for example, Freedberg 2003, Hecht, Schwartz, and Atherton 2003, Lopes 2009). Moreover, there is psychological evidence indicating that the development of drawing capacities supports the development of perceptual expertise and cognitive processes. Specifically, Aaron Kozbelt has shown that drawing skill influences performance in visual analysis tasks among expert draftsmen (2001; Kozbelt and Seeley 2007), which suggests that artists' productive practices influence their perceptual and cognitive abilities (Ruskin [1857] 1971, 27–28).

As shown by David Freedberg (2003), the capacity to produce precise drawings and illustrations of specimens was a critical instrument for the research into natural history undertaken by members of the Academy of Linceans, a scientific circle founded by Federico Cesi (1585–1630) and his friends. (This capacity can be called an an *artistic* skill because such illustrations rely on the use of tools, depiction principles, and systems of social learning of well-known artistic traditions.) Anatomists like Vesalius (about 1550) used extraordinary pictorial skills, as did the microbiologist and neuroanatomist Santiago Ramón y Cajal (1911) in communicating his histological observations with the microscope (Newman, Araque, and Dubinsky 2016). Scientific treatises have long been illustrated with pictorial exemplifications, and scientists specializing in this craft have been acknowledged for their excellence. Note, for instance, the popularity of Robert Hooke's *Micrographia* of 1667, which for the first time included detailed plates of what could be seen only with the aid of a microscope or telescope. These examples demonstrate that pictorial exemplifications were essential for developing analytical skills needed to identify biological kinds (Wilson, Barker, and Brigandt 2007) and to communicate the results of empirical enquiries carried out with these analytical skills. Consistent with Elgin's (1993) thesis, these examples illustrate that artistic drawing skills were essential in providing both psychological and communicational scaffolds for scientific understanding. (See Sterelny 2010, Sutton 2010, and Wimsatt 2014 on the importance of scaffolds in cultural cognition.)

A clear example of the dependence of scientific cognition on artistic practices is found in the mutual influence between the tools of optics and naturalistic European painting (Kemp 1990). From as early as Alberti ([1435] 2011) pictures have been treated as retinal prostheses, artifacts that record the projection of reflected light from the environment onto a two dimensional surface. This model facilitated the development of more careful and precise methods for exploring and documenting the structure of the natural world. This relationship was also influenced and inflected by an understanding of the nature of the psychological relationship between the consumer and the work. The perspectival systems developed in Renaissance painting produced well-known perceptual distortions that led to the development of systematic workarounds to counteract them (Kubovy 1986; Hyman 2006). The development of systems of perspective was thereby a step in the process of analyzing the limitations of our perceptual analysis skills and creating tools to overcome these limitations.

There are also contexts in which judgments about aesthetic properties play important epistemic roles in scientific decision making. The specific relation that obtains in these cases may be *aesthetic skills → scientific decision making*. Philosophers of science have demonstrated that researchers' sensitivity to aesthetic properties—such as beauty, simplicity, proportion, and coherence—is integral to scientific judgment. This claim has been developed to account for decision making in science in general (McAllister 1989, 1996; Thagard 2005) and in mathematics in particular (Montano 2014).

III. THE DEPENDENCE OF ARTISTIC CREATIVITY ON SCIENTIFIC INNOVATION

To establish the codependence thesis as plausible, we can also rely on evidence that the reciprocal of *artistic innovation → scientific innovation* obtains in highly significant historical contexts. That is, we can rely on contexts in which scientific cognition and inventions ("scientific scaffolds") are necessary conditions for cultural innovation in the aesthetic and artistic domains. A rich body of historical evidence supports this.

The Greeks, for example, did not clearly distinguish empirical investigation from artistic revelation or either of these from philosophy and theology. In that spirit, they classified music with mathematics. If this was because they found mathematics useful for theorizing about and teaching music, we might have an early instance of *scientific innovation → artistic innovation*. It was the Greek mathematician and geometer Pythagoras (about 2500 BP) who first investigated the relation between pitch and the length of vibrating strings. As is well known, Aristotle not only philosophized, including about art, but also wrote on physics and natural history. He discoursed on music theory, the construction of musical scales, and on optics and perception. Vitruvius Pollio (about 2000 BP), a Roman architect and engineer, analyzed, among other things, the acoustic properties of theaters (1914 Bk. 5 §6–8; see Boyer and Merzbach 2011). It was Vitruvius (Bk. 3, § 1) who theorized the ideal bodily proportions as based on whole-number ratios—as exemplified later in Leonardo da Vinci's (about 1470) image of Vitruvian man—and who advocated that these same ratios be used in buildings for their aesthetic advantage. This would be an early instance of *scientific innovation → aesthetic/artistic innovation*.

It was a different proportion, the so-called golden ratio, that fascinated Pythagoras and Euclid (about 2300 BP). It is a measure sectioned into a and b with the property that $a + b$ divided by a is equal to a divided by b, which is know as φ and is expressed as the irrational number 1.68103 . . . . This ratio featured in Greek and later architectural and sculptural design. It was said to have been used by the famous Greek sculptor Phidias (about 2450 BP) and takes its Greek-letter name from his. The use of the ratio has been widely praised for lending harmony and beauty to constructions and paintings (Livio 2002). In the twentieth century, it was championed for its aesthetic merit by Le Corbusier in his architecture.

(For detailed reviews of the literature on the golden ratio, along with skepticism about the allegation of its positive aesthetic character, see Berlyne 1971 and Green 1995. Note that scientific errors have sometimes inspired artistic innovations and that this might be a case in point.)

The themes and approaches of Greco-Roman times continued in the following 1700 years. The mathematics behind acoustic phenomena were studied and further developed by Galileo. The golden ratio was analyzed by Fibonacci (about 1100) and Kepler (about 1600). Meanwhile, the pursuit of scientific knowledge and the production of art were still not clearly separated. Many of those we think of as artists were equally concerned with scientific matters. As an example of the influence of scientific culture on artistic innovation (that is, *scientific innovation → artistic innovation*), Piero della Francesca (about 1450), along with other artists of the period, employed Euclidean geometry and algebra in the development of linear perspective and depth-representation in painting. As well, think of Leonardo da Vinci, who mixed the creation of artworks with sketched inventions, engineering diagrams, and dissection and anatomical studies, or of Dürer (about 1500) and his studies of animals. (Here they follow Alberti's ([1435] 2011) injunction that the artist should study the mechanics of movement in order to be able to represent action.) The scientific enculturation of prominent Renaissance artists is apparent in da Vinci's ([1651] 2005) treatise on painting, which reads like a scientific treatment of its subject, and in Dürer's writings on geometry and proportion.

Further, with respect to material culture and technical scaffolds, the *scientific innovation → artistic innovation* relation obtains in any context where artistic practices use artifacts developed by scientific practices and cultures (for example, optical artifacts like microscopes and cameras, cinematographs, computers and data gathering in arts using digital media). The relation also obtains whenever scientific theories and methods inspire new artistic ideas (for example, paintings inspired by discoveries in biology and geography, the use of stochastic mathematics to generate musical composition by Iannis Xenakis 2001, science in architecture).

A related case involves using a philosophical or scientific theory in order to assess the artistic merit of an artistic endeavor (*philosophical/scientific innovation → artistic innovation*). The aim of some scientific theories is to provide nomological or mechanistic explanations of artistic behaviors or phenomena (for example, empirical aesthetics or neuroaesthetic theories). But some other theories are used normatively and philosophically, as ways to interpret works of art that have had major effects on the course of art history. A clear example of this relation is found in the influence of Marxism in the arts. Neither Marx nor Engels developed systematic aesthetic theories, though Marx intended to do so (Hemingway 2014). According to their broader theory, art is part of the *superstructure*. As such it is a by-product of and gives expression to underlying social forces and dynamics. The considerable influence of Marxism and socialism on the arts (for example, Socialist Realism in the Soviet Union and, *mutatis mutandis*, Social Realism in the United States) came, then, more from its economic and political analysis of class struggle than from its aesthetic theory. However, while art may be a by-product of the socioeconomic *base*, it can reflect back on this base in a way that suggests social critique and revision (*scientific and philosophical innovation → artistic innovation*). This is crucial in explaining the importance of Marxism and socialism to some artists (such as Bertolt Brecht and Diego Rivera) and commentators on art and cultural history (such as Benjamin and the Frankfurt School; Baxandall and Morawski in Marx and Engels 1974).

A major scientific innovation in the nineteenth century was the account of evolution presented by Charles Darwin and Alfred Russell Wallace. This was the key scientific innovation that enabled future evolutionary accounts of art (an instance of *scientific understanding → artistic understanding*). However, Darwin had little to say about the arts in general. He used the term "art" to mean "skill" in almost all instances. But he did call birdsong music (1880, pt. 2, chap. 13), and he held that female mate choice in insects, birds, and other animals is based on aesthetic judgments of their mates' beauty (1880, pt. 1, chap. 3:92; pt. 2, chap. 11:329; pt. 3, chap. 21:616.) That is, he (wrongly) saw all perception-based pleasure as aesthetic in character (S. Davies 2012). While he thought it was mysterious that music was avidly pursued, given its lack of "use to man in reference to his daily habits of life" (1880, pt. 3, chap. 19:569–570), he allowed that, like the stridulations of insects, song plays a role in courtship (1880, pt. 1, chap. 3: 87; pt. 3, chap. 19: 572). Wallace, for his part, held that music and dancing are adventitious by-products of our brainpower and excessive vitality. "As with the mathematical, so with the musical faculty, it is impossible to trace any connection between its possession and survival in the struggle for existence" (1889, 468). In a similar vein, Darwin's supporter, Herbert Spencer ([1857] 1910) argued that music is an outgrowth of emotionally heightened speech.

The common view among present-day evolutionary theorists is that art is a by-product or spandrel, without adaptive significance in evolutionary terms. But at the close of the twentieth century and with the move to naturalize aesthetics, others have argued that art's antiquity, universality, and pleasurableness imply that it was adaptive for our ancestors, either as a tool for seduction (Miller 2000, Dutton 2009) or for other survival benefits, such as forging group and interpersonal bonds (Dissanayake 2000). (For a review of recent theories and critical discussion, see S. Davies 2012.)

IV. THE CODEPENDENCE OF SCIENTIFIC AND ARTISTIC UNDERSTANDING IN THE SCIENCE OF ART

One thread that draws the arts and the sciences together is an interest in the cognitive skills deployed in artistic practice. For example, how do artists develop their productive practices from reflection on their own perceptual, emotional, and cognitive experience? Moreover, how are consumers' minds affected by the artifacts produced by artists? The nature of these psychological interactions renders the relation between the sciences and the arts a two-way street, fostering a reciprocal relationship between both (*scientific understanding ↔ artistic understanding*). This suggests that evidence for the codependence thesis is to be found in the cognitive sciences of art.

Some precursors of the empirical study of the arts date from the eighteenth and nineteenth centuries. During the eighteenth century, aesthetics and the philosophy of art were clearly established as subjects for philosophical theorizing. A representative work here is Baumgarten's *Aesthetica* ([1750] 2014). Baumgarten construed aesthetics as involving taste, not merely sensory awareness, and attempted to use deductive logic to distill the scientific laws that governed beauty and aesthetic appreciation (Davey 2009). Meanwhile, the nineteenth century saw the arrival of experimental psychology, with particular interest in perception. Gustav Fechner (1876), Hermann von Helmholtz (1895), and Wilhelm Wundt (1908) performed experiments on the golden ratio and on visual art and music. Helmholtz influenced the scientists—in particular, Michel Chevreul—whose work on interactions between colors was the ultimate source of George Seurat's pointillist technique (*scientific innovation* → *artistic innovation*). Famously, Seurat also copied *Mach* bands into his paintings to enhance figure ground segregation in the compositions (Latto 1995; Ratliffe 1992).

Scientists (Emch 1900; Birkhoff 1933; Eysenck 1941) in the early twentieth century attempted to distill formulas capturing the principles of beautiful geometric forms. By the midcentury, a less reductive and more familiar kind of art study was pioneered by Rudolf Arnheim (1954, 1970, 1982). Arnheim applied the principles of Gestalt psychology—which seek pattern, closure, and the like—to the appreciation of art (see also Ramachandran and Hirstein 1999). Daniel E. Berlyne (1971, 1974), who revived and modernized Fechner's psychophysics of art, argued that the attraction and pleasure caused by art was a function of its surprise, ambiguity, novelty, complexity, and uncertainty. More controversially perhaps, he argued that the response was most efficacious when it was at a moderate level. Colin Martindale (1990), another cognitive psychologist, was a critic of Berlyne on this last point. Martindale focused more on the vicissitudes of stylistic change and how this affects the aesthetic response. Art seeks novelty, Martindale maintains, and styles succeed each other in a predictable fashion. A more recent idea proposed by Rolf Reber, Norbert Schwarz, and Piotr Winkielman (2004) suggests that aesthetic pleasure comes with the ease with which the artwork is cognitively and perceptually processed. It has been argued that this view can be amended to account for obtaining enjoyment from complex, challenging artworks (Bullot and Reber 2013).

Neuroscientific explorations of the range of formal devices, abstractions, and compositional strategies artists employ in their works have served as the foundation for a new research program in *neuroaesthetics* (Zeki 1999; Livingstone 2002; Chatterjee and Vartanian 2014; Pearce et al. 2016) that extends to experimental research in a broad range of media—for example, dance (Bläsing et al. 2012), music (Peretz and Zatorre 2003; Huron 2006; Levitin 2006; Patel 2008; Koelsch 2015), and film (Zacks 2014).

Neuroaesthetics also provides an example of the *artistic innovation* → *scientific innovation* relation. A central assumption of neuroaesthetics is that artworks, like behavioral deficits studied in neuropsychology, reflect, and so can function as tools for revealing, facts about the neurophysiological and psychological mechanisms underlying ordinary perception (Zeki 1999; Cavanagh 2005). Related research employs digital image analysis techniques to study the image features and image statistics that underwrite our capacity to recognize the subjects of pictorial representations and sort them into stylistic categories (Bonnar, Gosselin, and Schyns 2002; Greene and Oliva 2009; Graham et al. 2012). This research has been used both to develop digital image analysis techniques and to further our understanding of the nature of artistic style.

It should come as no surprise that such a broad range of research in cognitive science has been dedicated to understanding artistic production and the nature of our interactions with artworks. Artworks are artifacts designed to trigger affective, perceptual, and cognitive responses that enable consumers to recover the works' expressive, formal, aesthetic, and broader representational content. The success of this communicative project requires artists to develop a systematic, albeit tacit, understanding of the relationship between the content of their works (for example, the structure of natural landscapes or the expression of emotions), their medium (for example, the geometry of optics or the physics of acoustic phenomena), and the science of perception (for example, Carroll and Seeley 2013b). One would expect, therefore, that the psychological relationships between artists, artworks, and consumers should be of interest to anyone who wishes to understand art. However, as noted above, a number of practical and philosophical problems have been raised for this view of the relation between science and art.

David Davies (2013) has introduced a distinction between *moderate optimism* and *moderate pessimism* that is useful in articulating general skepticism about the explanatory relationship between cognitive science and art. *Moderate optimists* (for example, Seeley 2011, 2013; Bullot and Reber 2013) begin with the assumption that artworks are communicative artifacts. The content communicated might be social or political criticism, some art theoretical point, a perceptual representation of a scene or object, the expression of emotional or aesthetic properties, or the artistic exercise of teasing the formal coherence out of a complex, abstract composition. Artworks are the vehicles that mediate this communicative exchange. Questions about the structure and content of artworks, artistic understanding, aesthetic experience, and other forms of artistic appreciation can thereby be approached from a computational perspective as questions about the ways in which consumers recover salient information from the perceptible aspects of artworks in order to engage with their content.

Psychology, psychophysiology, and neuroscience, among other disciplines, are fields that can be used to model the processes governing our interactions with artworks. Scientific research about perception can contribute to clarifying a range of debates in aesthetics, including debates about aesthetic attention, the nature of film, and pictorial representation (Carroll and Seeley 2013a; Nanay 2016). Research from these scientific fields can contribute information to help confirm existing theories, adjudicate standing debates, and in some cases resolve long-standing questions about the nature of art and associated artistic practices (Seeley 2011). For example, research from the psychology and neuroscience of dance supports the notion that metakinesis, or a form of kinesthetic understanding, underwrites audience engagement with choreographed dance works (Montero 2006, 2013; Carroll and Seeley 2013b). And Margaret Livingstone (2002) has shown that Leonardo manipulated spatial frequency information in the surface of the *Mona Lisa* to produce her enigmatic expression, both confirming and modifying Gombrich's (1950) account of the painting by providing a mechanism to explain the dynamics of our perceptual interactions with its depicted subject.

Moderate optimists are positive about the extent to which these kinds of explanatory relationships between science and art generalize. They argue that answers to questions about the nature of art often require that we look under the hood to evaluate whether our best models of artistic practice match to the psychological details of our interactions with artworks. Where the results of this kind of research contribute to our understanding of individual artworks and associated artistic practices, we should embrace them and incorporate them into our understanding of art and artistic practices.

Moderate pessimists (for example, D. Davies 2013) share many intuitions with moderate optimists. However, they question the explanatory scope of empirical results. In particular, they question whether these results generalize to theoretical and normative questions concerning the nature of art and artistic practices. Empirical studies can be used to confirm or disconfirm the conceptual schema provided by philosophers of art, but in and of themselves such studies do not provide material sufficient either to adjudicate among competing theories or to provide independent resolutions to standing philosophical puzzles.

The view of the relationship between empirical results and conceptual analysis that Davies presents is unreasonably austere. Theorizing does not happen in a vacuum. The discovery of novel psychological facts concerning the nature of our engagement with artworks has the potential to influence the subsequent modification or development of conceptual schema. Of course, there is no reason to think this will always be the case. It is an open empirical question whether, and to what extent, empirical facts constrain and influence theory building in any particular context. The moderate optimist embraces this fact. The moderate pessimist, therefore, owes us some principled reason to believe that the kind of information collected in cognitive science is *never* germane to conceptual analysis, theory building, and the explanation of normative assessment. Short of any such reasons, moderate pessimism looks to collapse into an austere version of moderate optimism.

Some moderate optimists (for example, Seeley 2011, 2013; Bullot and Reber 2013) and pessimists (Hyman 2010; Noë 2015; Langer 2016) have argued that the methodology adopted in empirical studies of the arts fails to *locate art*. Research in cognitive science and aesthetics rests on an assumption that our interactions with artworks depend on no more cognitive apparatus than our ordinary affective, perceptual, and cognitive interactions with the world. Consequently, pessimists argue that empirical results may help explain how we perceive objects in depth in a painting, the dynamics of a sculptural composition, or the expressive content of choreographed movements. Likewise, empirical results may facilitate explanations of our preferences for artifacts that we categorize as art. But empirical results do not do so in a way that explains why these representations, formal aesthetic properties, or expressive qualities count as *artistically* salient qualities of the work, why we categorize these artifacts as distinct from their ordinary, nonartistic affective, perceptual, or cognitive counterparts. This is a difficult problem. It often leads to an extreme pessimism about the relationship between science and art (McFee 2011; Noë 2015).

Extreme pessimists argue that the location of art lies in the normative conventions that govern artistic practice and shape our appreciative judgments about individual artworks. The influence of these normative conventions in our engagement with art, they argue, lies outside the purview of our perceptual engagement with artworks (Danto 2001; McFee 2011). On the one hand, explanations of the application of these normative conventions in artistic judgments will call upon the same sets of cognitive practices deployed in the application of normative conventions in any domain. So, again, they will fail to locate art. On the other hand, the same cognitive processes will be involved whether these conventions are applied correctly or incorrectly, whether the resulting judgments are apt or not. Therefore, cognitive science will not be of any use in understanding how these normative conventions define our understanding of art or shape our appreciative judgments. Cognitive science, hence, fails to locate art because it falls short in helping us understand *the normative dimension of artistic appreciation*. This is also a difficult problem.

The first step to addressing these two difficulties is to note that our knowledge of the normative conventions that define categories of art does not float free of our perceptual and cognitive engagement with artworks. For instance, one source of our appreciative judgments about a work is knowledge of the normative conventions governing artistic production in an art-historical category. Knowledge of these conventions has the capacity to modulate our perception and subsequent aesthetic experience of a work (Walton 1970). We can explain these effects in terms of the role played by top-down processing in selective attention and object recognition (Pessoa, Kastner, and Ungerleider 2002; Kastner 2004; Barrett and Bar 2009; Pessoa and Adolphs 2010). If so, we can explain how knowledge of the normative conventions constitutive of a category of art guide attention, modulate our perceptual engagement with an artwork, and in some cases shape our experience of it.

It is here that a moderate pessimist will draw a line in the sand. Psychological analyses of the role played by normative conventions in our perception and subsequent understanding of a work are interesting and important. But they involve the application of previously worked out conceptual schema to our interactions with individual artworks. The critical piece of the puzzle is to explain the normative conventions themselves, not how they are applied.

The moderate optimist might just bite the bullet on this point. Cognitive science is well suited to explain *how* normative conventions govern our engagement with artworks. But perhaps it is ill suited to explain *why* we appeal to those conventions as opposed to others. However, this point too could be challenged. Recent evolutionary accounts of culture and the arts (for example, Dutton 2009; Sterelny 2010; S. Davies 2012; Wimsatt 2014) fall under the umbrella of cognitive science. Their account of cultural change is poised to help answer *why* questions about the normative conventions that govern our interactions with artworks. Further, the normative conventions that define different categories of art are the outcome of a complex social negotiation mediated by the communicative exchange between artists and artistic communities. Therefore, facts about our perceptual engagement with actual artworks have the potential to help elucidate important aspects of the cultural evolution of art-historical categories.

We touch finally on an objection due to Gopnik (2013, also Chatterjee 2013). He notes that our interest in art has always been an interest in the meanings of artworks, in their semantic content. This is as true of current conceptual and abstract modernist works as it was of seventeenth-century Flemish landscapes and Baroque paintings of religious themes. The perceptual and aesthetic qualities of a work are some of the tools artists have used to facilitate our understanding of this semantic content. But it is the particular semantic content that matters in the end. The methods of cognitive science give us no purchase on mental content at this latter grain of particularity.

This is also a compelling and difficult problem. But, again, the moderate optimist can simply bite the bullet. Matters of interpretation can be left to critics, art historians, and critical theorists. It is sufficient to establish the relationship *scientific understanding → artistic understanding* in this case by recognizing that categorization processing plays a regulative role in our affective, perceptual, and cognitive engagement with artworks, that artworks are fine-tuned to these processes via the ongoing communicative exchange between artists and their artistic communities, and that research in cognitive science can thereby contribute, in at least some cases, to our understanding of the nature of art and associated artistic practices.

V. CONCLUSION

To sketch a defense of the codependence thesis, we have argued that it is possible to retrace significant dependence relations between the arts and the sciences over the long course of human history. Scientific culture has enabled artistic innovations in a variety of contexts, and the arts have likewise influenced a range of scientific developments. Had these dependencies not occurred, the arts and sciences would be revealed as very different from what can be discovered through careful historical enquiry. A major shortcoming of the Two Cultures view and of the pessimistic account of art–science relations is therefore that these views have contributed to silence the philosophical history of such dependence relations. Further, although skepticism about neuroaesthetics and other scientific contributions to our understanding of art remains prevalent, this skepticism does not undermine either our codependence thesis or our argument from dependence relations.

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